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FLIGHT TEST AND EVALUATION OF HELIPORT LIGHTING FOR IFR

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National Aviation Facilities Experimental Center

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DECEMBER 1972

FINAL REPORT

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DEPARTMENT OF TRANSPORTATION

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Systems Research & Development Service

Washington D. C., 20591

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16. Abstract

Various approach lighting system patterns, developed through mockup and VFR flight testing efforts, were evaluated to determine their effectiveness in providing visual guidance for helicopter IFR approach and landing operations. Four basic lighting configurations were flown, under actual IFR weather conditions, by experienced helicopter subjects pilots. As a result of information collected through in-flight recording of objective data and post flight completion of pilot questionnaires, one of the lighting patterns was chosen as most effective for the conditions specified.

Details of illustrations in this document may be better studied on microfiche

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INTRODUCTION

Purpose.

The purpose of this project was to evaluate the effectiveness and suitability of several proposed heliport IFR approach lighting system configurations, and to determine which, if any, would provide the most economical yet adequate visual guidance.

Background.

The first approach lighting evaluation for helicopter operations was conducted at Fort Belvoir, Virginia in a joint FAA/Army program during 1964. Information available at that time indicated that helicopters would be operated on approach angles of about 12 to 30 degrees. These steep angles resulted in trials being conducted on various patterns of lights, all located within the boundaries of the helipad perimeter lighting. The results of this program established that the lowest approach angle (12 degrees) exceeded the normal operating limitations of the aircraft participating in the program, the CH-21C primary helicopter used. Consequently, considerable doubt existed concerning the validity of the operating requirements established for the program. The evaluators recommended additional tests to be held later due to the problems that had arisen in the Fort Belvoir program.

During the intervening period more realistic operating requirements for helicopters have been established, and approach angles of six degrees and lower have been specified for present day helicopters. This requirement has not been verified, however, since there exists no standard ILS equipment developed specifically for helicopters. Systems of this type are just now being acceptance tested in the U. S.

A decision to resume testing of lighting systems to support both VFR and IFR helicopter operations was made in 1967, however, and the effort was begun immediately. The development of criteria under which the VFR lighting evaluation should be conducted was rather straight-forward, since a good deal of VFR helicopter operational experience had been gained during the intervening three year period. Accordingly, a joint FAA/Military helicopter VFR lighting evaluation was accomplished during 1968 at Fort Meade, Maryland, and the results were published during March of 1969 in final report form.[1]

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(1) Thomas H. Paprocki, Flight Test and Evaluation of Heliport Lighting for VFR, Report No. FAA-RD-68-61, March 1969, NAFEC, Atlantic City, New Jersey.

Efforts to undertake and accomplish a similar evaluation for helicopter IFR lighting systems progressed less rapidly, principally because of the lack of information about and experience with IFR helicopter operations. Numerous meetings between representatives of FAA, the Military services, and other helicopter operators, in effect a joint advisory group, took place in an effort to develop realistic testing criteria at a time when IFR helicopter procedures themselves were still under development. Agreement on the criteria to be applied, techniques of evaluation and configurational dimensions to be used as a guide was finally reached during early 1970. The actual IFR lighting evaluation effort took place at NAFEC and at the Naval Air Test Center (NATC), Patuxent River, Maryland, during 1971 and 1972.

<u>Description of the System</u> (See Figure 1).

A system of 182 individual PAR-56, 200 watt airport approach lighting fixtures was installed in the approach zone of Runway 35 (presently closed) at NAFEC in such a manner as to serve as an approach lighting test system for a helipad established on the hard-surfaced underun area adjacent to the Runway 35 threshold. The lights were circuited so as to permit display of a number of different proposed heliport IFR approach lighting patterns. A capability for varying lamp intensity from zero to full brightness was included in the system. Pattern changes could be accomplished within seconds from the lighting control structure nearby, and full VHF and UHF ground-to-air communications were provided.

The helipad landing area was outlined with a standard yellow VFR perimeter pad lighting system, as developed during the VFR evaluation effort (Figure 2).

A microwave electronic Instrument Landing System (ILS) was provided and a test aircraft instrumented so as to permit the subject pilot to execute instrument approachs during the actual weather data collection runs (Figure 3). The ILS equipment itself was not under test or evaluation but rather served as a test facility or evaluation tool. Radar vectors were used to position the test helicopter for each approach.

Several smaller constant current regulators were utilized, rather than one or two larger capacity units, so as to permit maximum flexibility of control and switching. In addition, all power cables were of the weather resistant type installed above ground to facilitate rapid changing of the power circuits. An added advantage to the multiple regulator installation was that, with so many power supplies, the maximum voltages present in any one circuit were lower and thus less hazardous.

The test bed aircraft used at NAFEC was a Bell Military UH-1H helicopter obtained through loan from the U.S. Army (Figure 4). Navy helicopters of the H-3, H-46 and H-53 type were later used for testing of like systems installed at N.A.T.C. Patuxent River, Md.

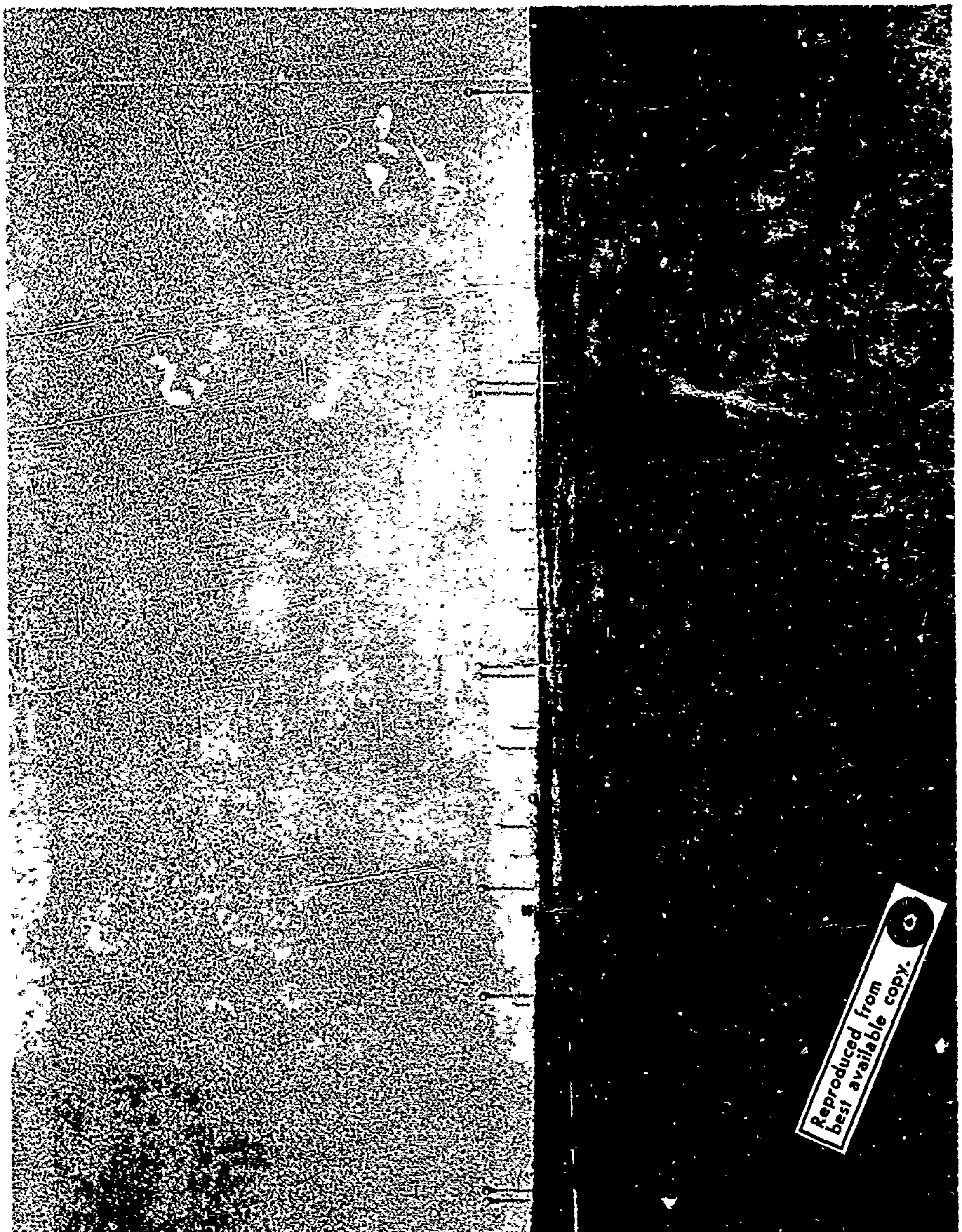

FIGURE 1. EXPERIMENTAL SYSTEM

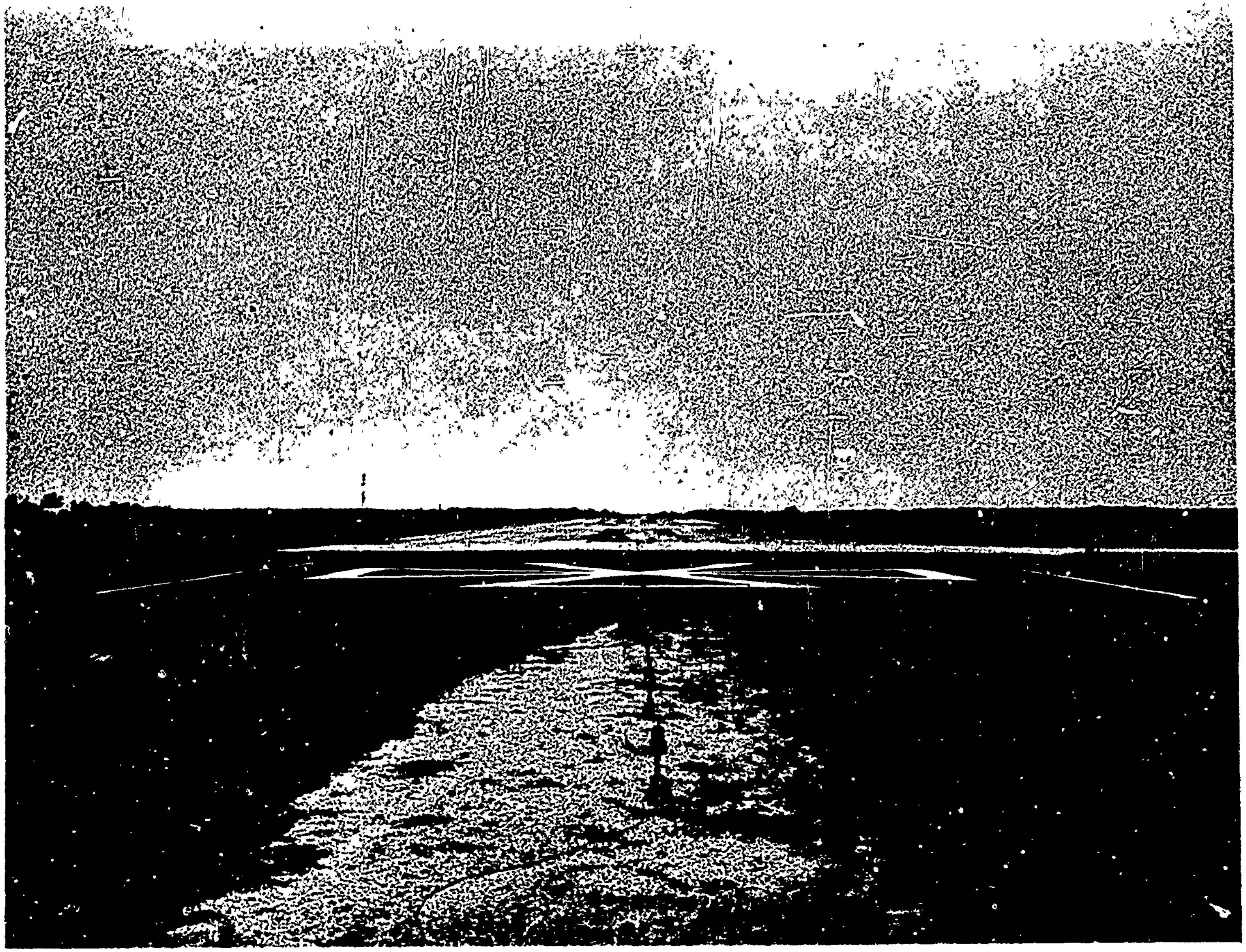

FIGURE 2. HELIPAD PERIMETER LIGHTING

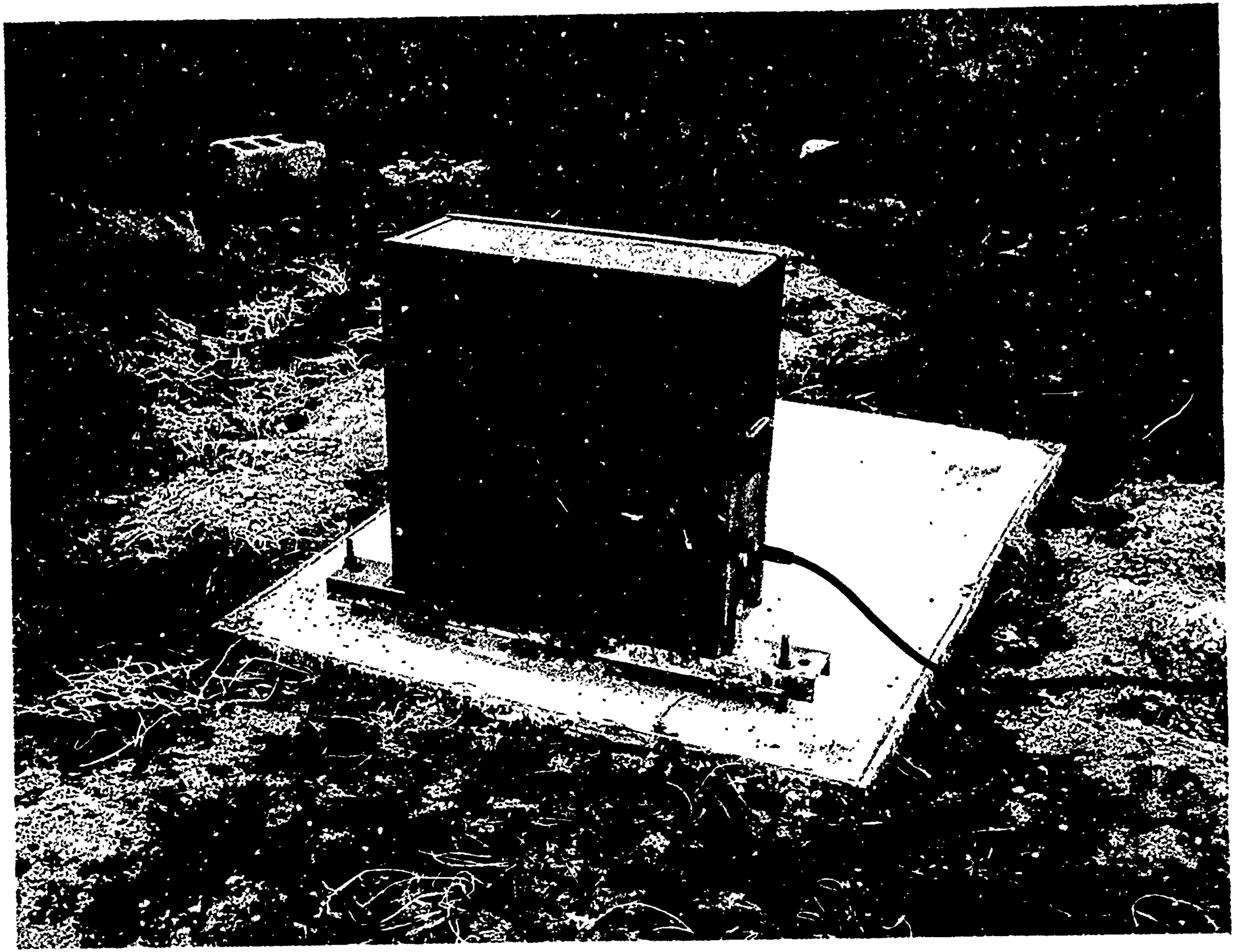

FIGURE 3. MICROWAVE ILS GROUND EQUIPMENT

FIGURE 4. ARMY UH-1 "HUEY" HELICOPTER

DISCUSSION

Test Design.

Initially it was thought that the choice of the most suitable and adequate IFR helicopter approach lighting system could be made on the basis of data obtained from flight evaluations conducted under VFR conditions using simulation techniques to approximate the restricted visability found under actual IFR conditions. It was felt that this would be a more desirable testing technique to use than actual weather flying, since it would be possible to schedule evaluation flights and to utilize a much larger cross-section of subject pilots. Dependence upon the occurrence of real IFR weather might severely restrict both the number of flights that could be accomplished and the number of subjects that one could reasonably expect to have on hand. A realistic analysis of the IFR simulation techniques available for use, however, coupled with a limited amount of flight testing of these methods of simulation, revealed that it would be necessary to obtain data under actual IFR weather conditions if any valid conclusions were to be reached. Even though such a course of action would prolong the testing period significantly, it was decided that the actual weather flight testing technique was the only reliable path to follow. With this in mind, it was decided to conduct the evaluation effort at NAFEC and at N.A.T.C., Patuxent River, Maryland concurrently, since helicopters and qualified instrument rated pilots could be made available on an "on-call" basis at these locations.

The configurations of approach lighting to be tested were evolved from a number of patterns suggested or recommended by individuals with a considerable amount of experience in helicopter instrument operations. They had, of course, used the operational parameters to be described later in this report as a basis for developing their system design. Approximately ten of the suggested patterns were displayed to the entire advisory group, using a miniature mock-up board, for consideration. The three most promising patterns, as determined by the group, were then designated as the configurations to be compared and evaluated in full scale, and under actual IFR weather conditions. These test systems were designated patterns "A", "B" and "C", (Figures 5, 6 & 7) and will be so referred to throughout the report. In general, it can be said that pattern "A" was essentially a "lines-toward-the-pad" configuration, "C" essentially a "bars-toward-the-pad" configuration, and "B" a combination of the two concepts. All three patterns were, however, somewhat similar with respect to width, length and directional geometry, since the operational parameters virtually dictated these aspects of the design. At approximately mid-point in the flight evaluation effort the project team met to determine whether any changes or alterations to the testing technique were necessary. It was agreed that the overall evaluation procedure was working just about as had been planned, and that the data obtained up to that time seemed to be of form and quality suitable for the ultimate determination of which approach lighting pattern would be most satisfactory. Several of the subject pilots had, prior to the meeting, suggested that the

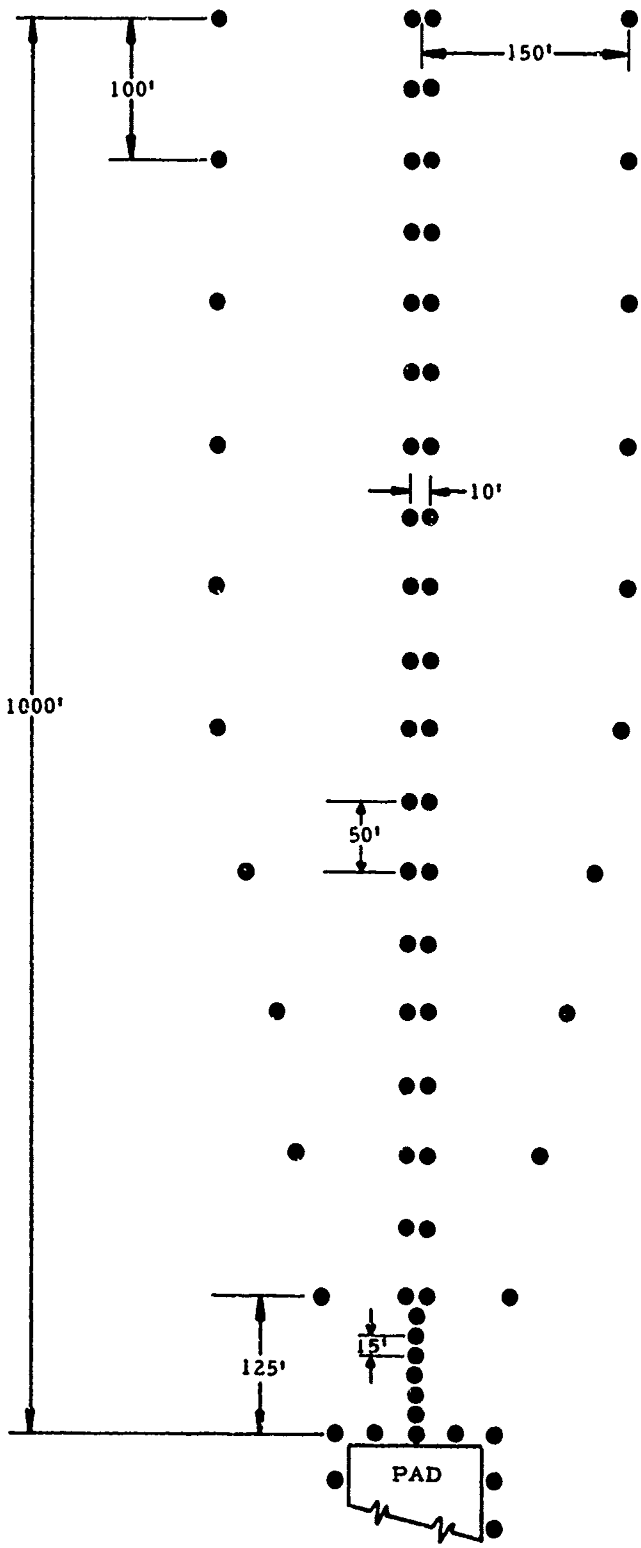

FIGURE 5. PATTERN "A" CONFIGURATION

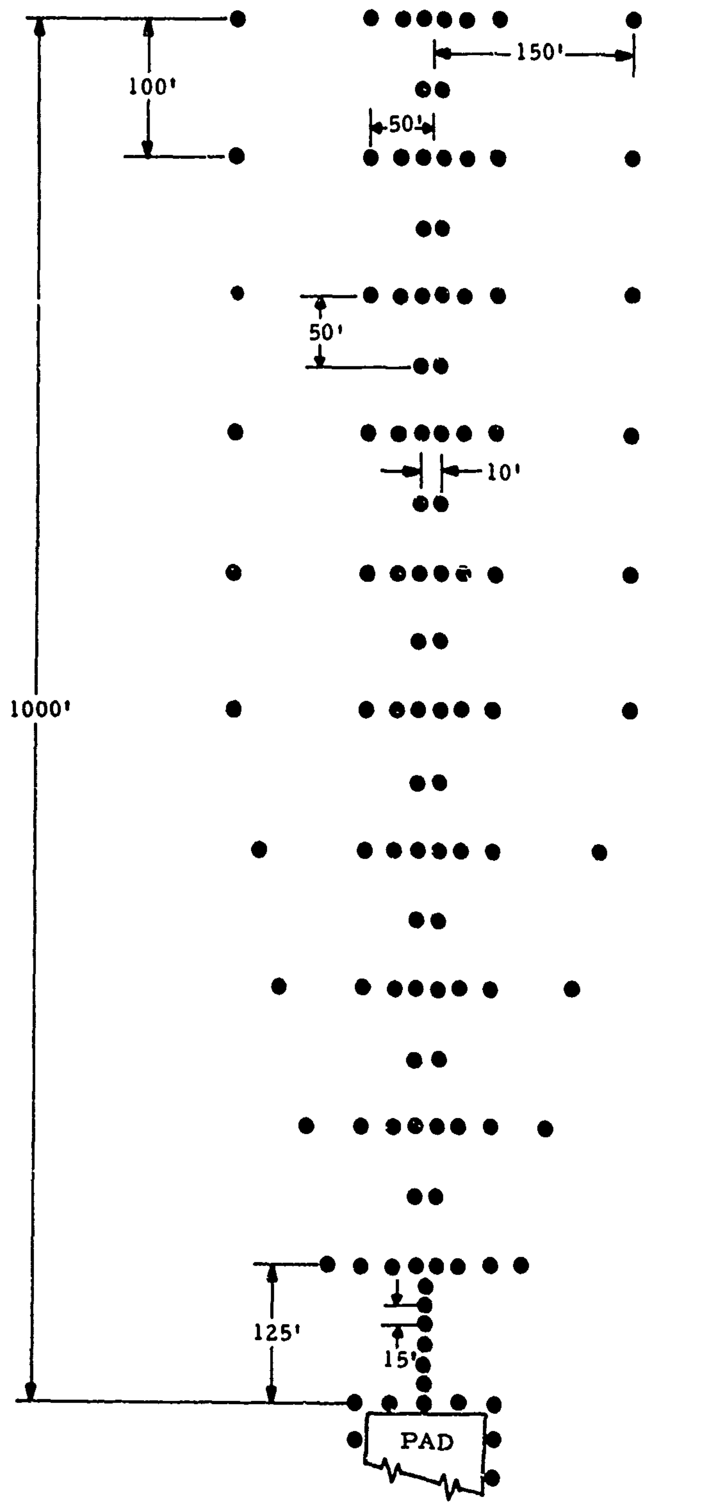

FIGURE 6. PATTERN "B" CONFIGURATION

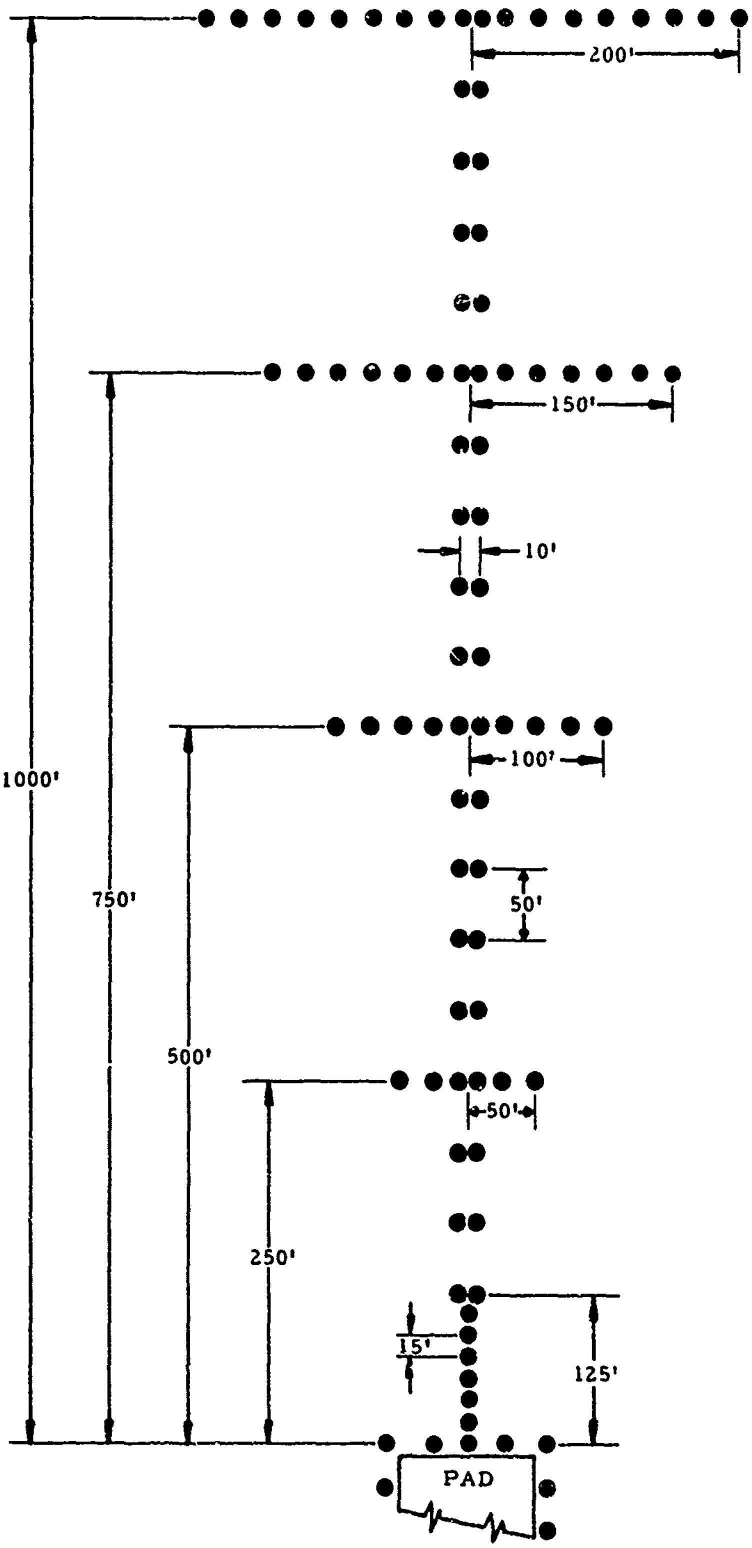

FIGURE 7. PATTERN "C" CONFIGURATION

"B" pattern might be improved by the elimination of two rows of lights (those at each hundred foot station from the pad and 25 feet on either side of the centerline of the system) that seemed to provide little in the way of guidance and much in the way of excessive glare. The matter was discussed in detail, and a decision reached to accept the modification as an obvious and desirable change in the pattern. It was felt that sufficient time and probable weather occurrences remained to permit valid evaluation of the altered system. The "B_{mod}" pattern (Figure 8) was thereafter substituted for the "B" pattern and considered, from that time onward, as one of the three basic configurations under evaluation. Though not actually part of the three basic and one evolved approach lighting patterns, the wing bars as shown in Figure 9 were included as a common component in all of the patterns. They were meant to provide a measure of supplemental roll and alignment guidance for the pilot once he had reached the point in his approach whereafter the actual pad perimeter lighting system might be masked from view by the nose-up landing attitude of the helicopter. These lights were of the same high-intensity type as those of the approach lighting systems. They were, however, used at lower intensity settings throughout the evaluation, and could just as easily have been of a medium intensity type.

The high-intensity lights of the various approach lighting patterns were habitually energized at the highest intensity settings possible (100% - 6.6A) except when temporarily turned down at the pilots's request.

The use of uni-directional 200W PAR type lamps throughout the approach lighting system was specified to ensure that sufficient intensity was available in the event that it was needed. A pre-determination was made that this particular size and type of lamp would be the most likely to provide sufficient brightness without compromising any system effectiveness with excessive glare. Helicopter pilots are more likely to be affected adversely by high lighting system brightnesses, since approach speeds are slower than those of most conventional aircraft and expose the pilot to glare conditions for longer periods of time.

Lower intensity 1020 Lumen lamps were used for the helipad perimeter lighting portion of the system, since these are the type specified for the purpose. It was anticipated that this portion of the system would not be discernable at extreme ranges under the visibility restraints of instrument weather. This was not considered to be a detriment, however, since a readily identifiable and effective approach lighting system would be sufficient to guide the pilot in to the closer range at which the helipad perimeter lighting system could be identified as outlining the landing area. Since conventional runway edge lights are not required to provide approach guidance under restricted visibility conditions, similar reasoning leads us to conclude that the helipad perimeter lighting system need not perform a like function of providing approach guidance for helicopter operations.

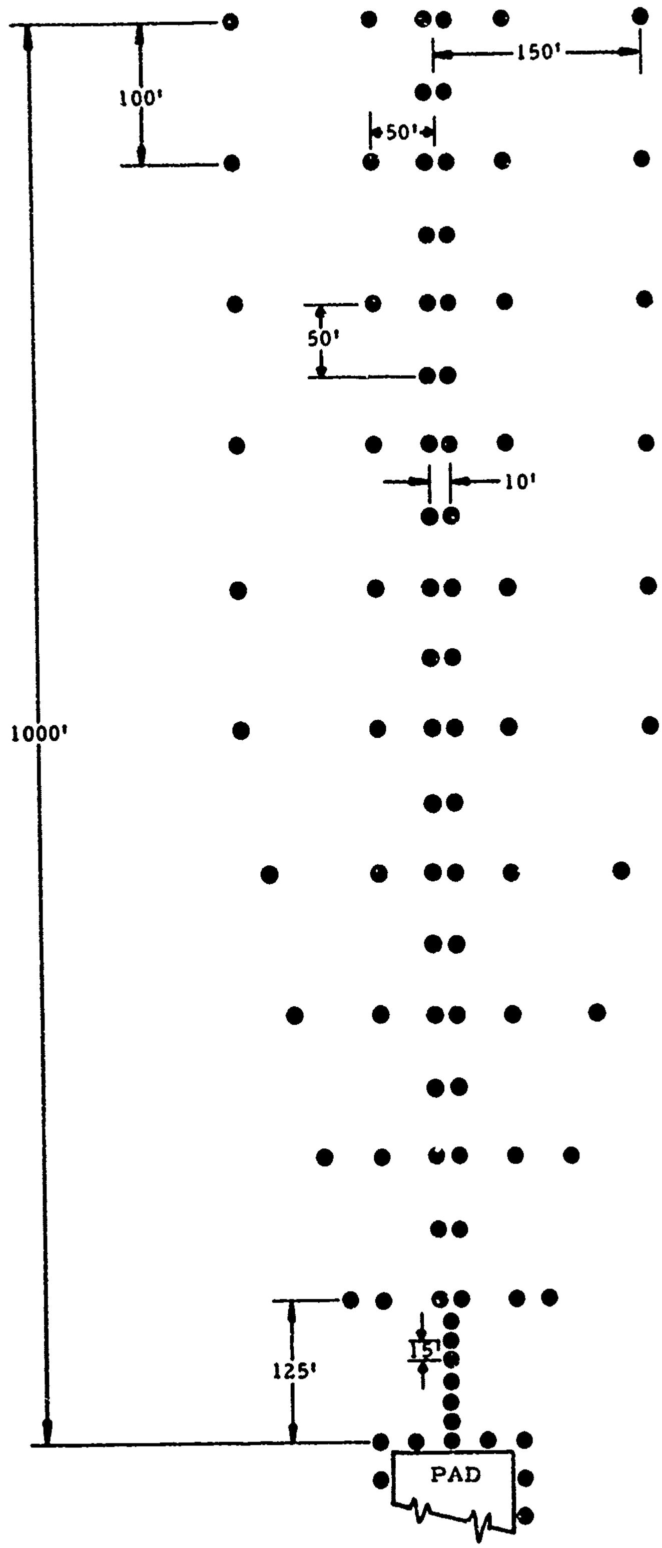

FIGURE 8. PATTERN "B_{mod}" CONFIGURATION

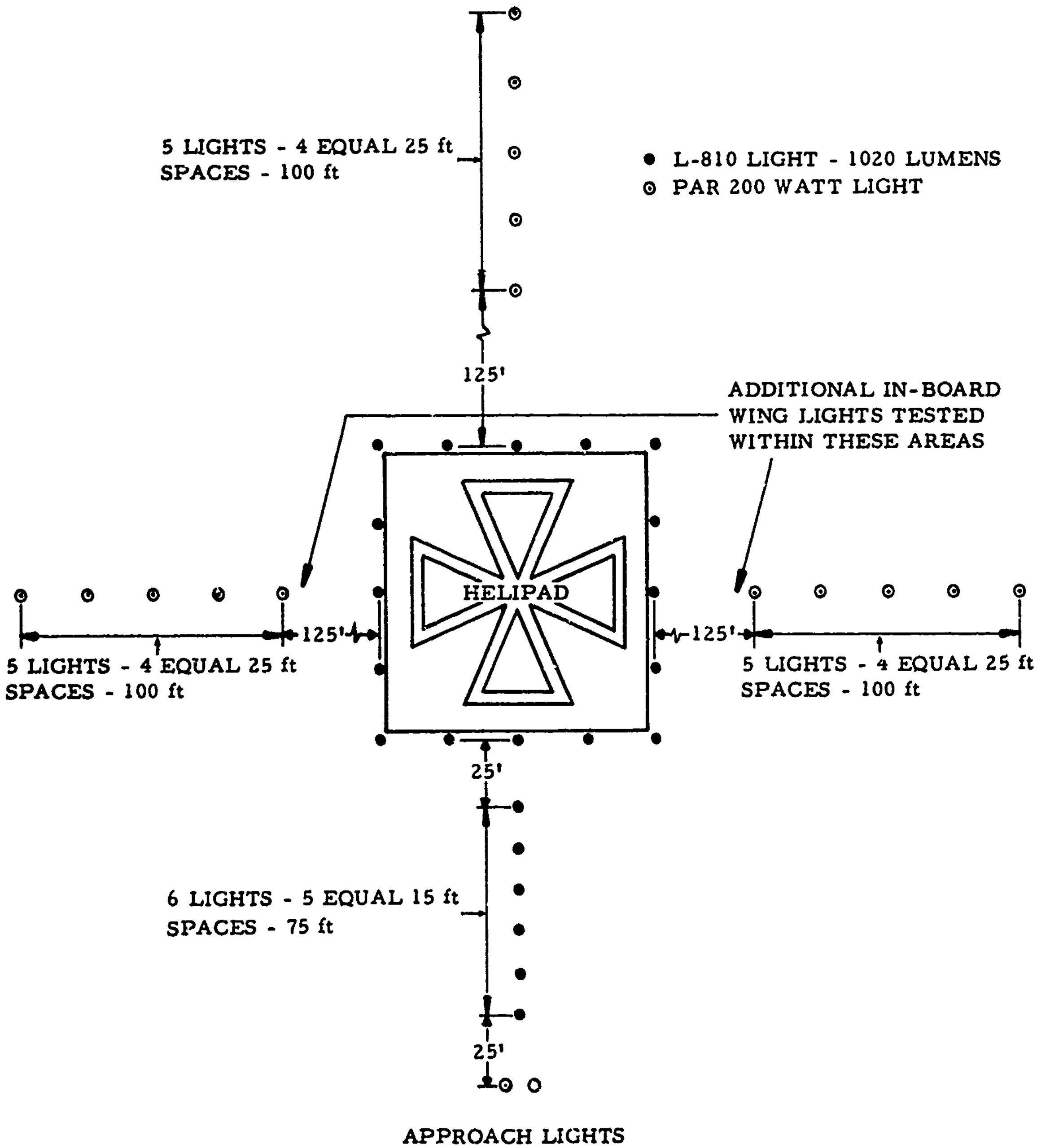

FIGURE 9. WING BAR CONFIGURATION

The military UH-1H "Huey" helicopter used during the actual weather flight evaluation at NAFEC was chosen for a number of reasons, even though it was recognized that it was not the type most likely to be encountered in civil helicopter air-carrier operations. Due to it's widespread use throughout the military services, the "Huey" was the helicopter with which more FAA and military pilots would be familiar. Further, it was readily available through loan from the U.S. Army, and provided an admirable test bed from the viewpoint of ILS electronic equipment installation, observer seating location, ease of maintenance, etc. Supplemental testing with helicopters of larger sizes and types more closely approximating those in civil use confirmed that the flight characteristics of the "Huey" were similar enough that data obtained would be applicable to those other types as well.

Among the larger types of helicopters flown while making this "suitability" determination were the Military H-3, the H-53, the H-46 and the H-52 types.

As was mentioned earlier, an additional evaluation site was established at the Patuxent River Naval Air Test Center so as to permit utilization of the substantial aircraft and pilot resources normally assigned to that facility. Unfortunately, difficulties encountered with the installation of a suitable RADAR Ground Controlled Approach (GCA) System to support the evaluation effort and subsequent development of flight procedures prevented commissioning of the facility in time to obtain any actual-weather flight data. The installation was used, however, to make a portion of the "suitablity" determination previously mentioned, and to evaluate a variation in "wing-bar" configuration after the NAFEC test facility had been shut down.

The bulk of the "subjective" pilot opinion obtained during and as a result of the actual weather flight testing at NAFEC was furnished by four NAFEC helicopter pilots assigned to the evaluation effort. While this is, admittedly, a small number of subjects from which to draw conclusive opinion data, it is about all that could be reasonably utilized considering the nature of the evaluation and the test conditions established. It was felt that had a greater number of pilots been assigned to the project as subjects, they would not have experienced sufficient exposure to the actual weather conditions encountered.

The possibility of utilizing a rotation of subject pilot assignments was considered, but rejected as not providing any assurance that the participating pilots would have sufficient repeated experience, in actual IFR weather, on all of the systems under evaluation to render valid opinions. It was thought that the subjective opinions and comments from only a few thoroughly-experienced project pilots would be more valuable than a greater number of judgments from subjects having perhaps less-than-adequate exposure to the systems being evaluated. Additional considerations of specialized pilot training, the requirement for ILS

instrumentation and familiarity with its use, and the need for pilots with a knowledge of the pitfalls of subjective evaluation techniques all combined to make use of a larger subject group impractical.

After considerable discussion and research, the joint advisory group agreed to the establishment of the following minimum criteria and evaluation parameters:

1. Considering glide slope values of 3° to 6° as being the optimum for civil type helicopter operations, all flight test approaches were to be accomplished at the more critical 6° glide slope angle.

2. Taking into consideration the somewhat greater deceleration time of the heavier and larger types of helicopters, a decision height of 200 feet-above-terrain was established.

3. Minimum visibility, as reported, during which flight evaluation would be accomplished was set at one-quarter mile.

4. RADAR vectors to the ILS "gate" would be used, positioning the helicopter so as to intercept the ILS localizer and glide path on-course signal at a range of approximately three miles.

5. Final approach speeds of 40 to 90 knots to the flare point were considered acceptable.

6. The helicopter was to decelerate to a zero ground speed at or before reaching the hover point above the helipad.

In order to collect as much relevant objective data as possible, the project manager accompanied each data collection flight as observer to record such information as follows:

1. Date and time of each approach.

2. Reported weather.

3. Actual weather (ceilings, visibilities, etc.) as observed from the aircraft during each approach.

4. Indicated altitude upon first sighting lights.

5. Pilot comments as to ease of identification, pattern appearance, type and quality of visual guidance, etc.

6. Pattern displayed and intensity used.

7. Pilot flying each approach.

Test Procedures and Conditions.

So as to be as certain as possible of taking advantage of whatever restricted visibility weather occurred at NAFEC, a system of "weather stand-by" or "on-call" status for pilots and aircraft was set up. During the periods of normally heavy and frequent fog conditions within the immediate area, the Fall and Spring seasons, the project manager and his project pilot continually monitored prevailing weather conditions and Weather Bureau forecasts. Whenever it appeared that restricted visibility conditions, as a result of fog or other forms of precipitation, would occur, the "stand-by" or "on-call" condition was established. Two of the four subject pilots and the crew chief were alerted and instructed to be ready for immediate data collection flights in the event that the desired weather conditions developed. As a rule-of-thumb, pilots were called onto the base for duty whenever the ceiling and visibility reported reached 500 feet and 1 mile or less. The helicopter, with the two subject pilots and one observer, was launched as soon as the visibility decreased below one mile and/or the ceiling dropped to 300 feet or less.

Once airborne, the project pilots executed ILS approaches to the lighting patterns so long as the weather conditions resulted in reported ceilings within the 100 to 300 foot range and visibilities of 1/4 to 1 1/2 miles. When visibility conditions either improved or threatened to deteriorate to the point where further approaches would be impossible, the helicopter landed and flight testing was terminated.

On those occasions when conditions permitted a longer flight session, the back-up team of pilots was called upon to continue the data-collection effort.

The "weather-watch" and possible call-up situation was maintained 24 hours-a-day, seven-days-a-week for an 8 month period from October of 1971 to May of 1972. During this period the few occurrences of suitable weather having been missed can be attributed to either required maintenance downtime for the helicopter or nonavailability of assigned project pilots due to conflicting duties on other projects.

Normal flight procedure during data collection flight activities, as shown diagramatically on Figure 10, was to depart the helipad in a Southeasterly direction, climbing to and maintaining a 1500 foot altitude on a 150° heading until vectored to intercept the ILS localizer by NAFEC Approach Control. The ILS glide path angle was preset to 6° for each approach, with the localizer aligned along the runway 35 heading.

The subject pilot was responsible for all control of the aircraft, flying it from the command right-hand seat. The co-pilot, in the left-hand seat, handled communications with tower and approach control and acted as Safety Pilot for the exercise. Once established on glide path and localizer, the subject pilot flew the aircraft by crosspointer indication until such time as either he or the co-pilot picked up the approach

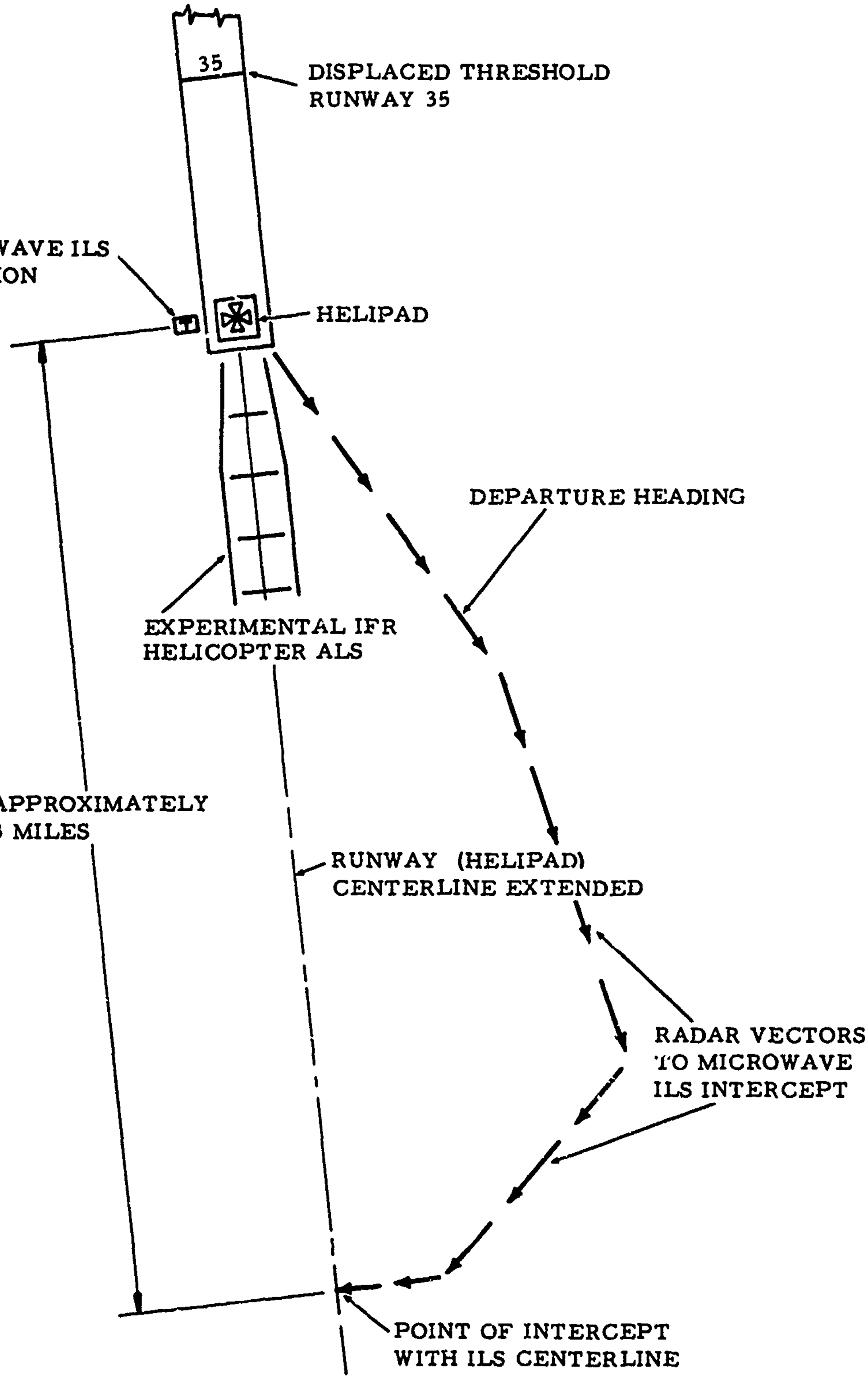

FIGURE 10. DIAGRAM OF FLIGHT PATTERN

lighting system under evaluation or else broke off the approach upon reaching the decision height of 200 feet-above-terrain without making visual contact with the lights. If visual contact was made at or above the decision height, one pilot or the other would announce "lights" so that the contact height for that approach and lighting pattern being flown could be recorded by the observer in the helicopter. The subject pilot then continued the remainder of the approach visually to a low hover or landing on the helipad using the visual guidance provided by the approach lights and pad lights. During the entire flight the observer made notes of the weather condition and other pertinent data using a hand-held tape recorder. This information was later transferred to a written logbook for subsequent study and analysis. Each of the two pilots executed a minimum of two approaches to each of the three different approach lighting test patterns per flight session, providing the weather conditions and visibility remained suitable.

Results.

As mentioned earlier in this report, data used to determine the results of this evaluation effort was of both subjective and objective nature. From the comments and opinions of the subject pilots, as expressed verbally during the flights to the observer and in written form on the postflight questionnaires, information about, and insight into the identification and guidance qualities of the lighting patterns was obtained. The additional statistical information, such as observed ceiling heights for each approach, altitude at which the "lights" was announced (Contact height), reported weather for each approach, etc., provided the objective data from which a measure of system effectiveness in providing early visual contact, prior to actual breakout from the obscuration, could be derived. A determination of the most suitable configuration of lights depended, then, upon analysis and interpretation of both forms of data.

Often, in attempting to choose the most suitable or desirable form of visual aid from among several, we must consider not only whether one system or pattern provides adequate guidance but also if its relative cost, in terms of equipment used and land areas required, is justified. In this particular instance, however, such cost factors did not enter into the selection of the most suitable system. Each of the four patterns tested required the same approximate ground area and involved similar equipment costs.

A total of 125 approaches in actual IFR weather conditions at NAFEC were accomplished during the 8 month period of evaluation. It is reasonable to estimate that flight testing was carried out during at least 75 percent of the occurrances of suitable weather within the period. As stated earlier in this report, aircraft downtime and pilot unavailability account for the remaining 25 percent estimate of opportunities missed. The breakdown of data collection approaches made, according to reported ceilings from the NAFEC Weather Bureau facility, was as follows:

No. of Approaches	Reported Ceilings
25	100 feet
69	200 feet
14	300 feet
8	400 feet
9	500 feet & above

In so far as was possible, each of the four assigned FAA helicopter test pilots was afforded equal opportunity to serve as subject pilot on data collection flights. It should be borne in mind, however, that the subject pilots were actually observing and accumulating experience with the various patterns even while serving as the Safety Pilot and not actually controlling the aircraft. It should be noted also that each of the four pilots selected for participation in the evaluation had a substantial amount of previous experience both in helicopter instrument operations and flight testing of visual aids of all types.

Objective Data.

A review of the data obtained and recorded by the project observer present in the helicopter on each data collection approach revealed that, of all the information gathered and tabulated (see Figure 11 for sample portion of data log sheet), the figures for observed ceiling height upon departure from the helipad before each run (hereafter referred to as "Departure Ceiling") and for recorded height at which the approach lights were first perceived and identified can be considered as the most important. Other data, such as prevailing winds; reported weather conditions; approach speeds and rates of descent; were of interest, of course, but not of primary importance. In order to obtain some figure that would indicate the relative effectiveness of the different lighting configurations in providing early visual contact, the average departure ceiling and contact height for each of the lighting patterns was calculated. The difference figure, that is contact height less departure ceiling, can be considered as a reasonably accurate estimate of the benefit in altitude or height before "breaking out" that each system afforded the pilot. Naturally, this figure cannot be relied upon for accuracy if calculated for single approaches, but when minor variations in observer technique, pilot attentativeness, and flight variations are averaged out over a large number of approaches with different pilots, the figures have merit in arranging the lighting patterns in order of increasing effectiveness for providing early visual contact.

MASTER RUN No.	116	117	118	119	120	121	122	123	124	125
DAILY RUN No.	3	4	5	6	7	8	9	10	11	12
DATE	3/31/72 ←								→	3/31/72
REPORTED WX	100/1½	100/1½	100/1½	100/¾	100/¾	100/¾	100/¾	100/¾	100/¾	100/¾
START TIME	0006	0016	0026	0035	0046	0058	0107	011[illegible]	0126	0135
PILOT	DEK	DEK	DEK	DEK	LAM	LAM	LAM	LAM	LAM	LAM
DEP.CLG.OBS.	290	350	300	350	200	250	225	220	[illegible]80	200
WIND REPORT	030 @13		020 @14	040 @12	050 @8	040 @9	030 @10	030 @10		020 @14
LTH.SYS.SEEN	900	800	ALL	800	ALL	900	800		900	800
CONTACT HEIGHT	380	380	400	400	450	400	400	350	330	400
VIS.AT MINS.				½		¼				
VIS.ON GROUND	3/4	½-¾	3/4	3/4	3/4	3/4	½	½		½
SINK RATE	800	750	700	700	1000	800	700	650	800	750
APPROACH SPEED	65	64	65	66	60	80	80	75	72	75
PATTERN	C	B_M	A	C	B_M	C	B_M	A	C	A
INTENSITY	100%					100%				
END TIME	0015	0025	0034	0042	0056	0105	0115	0123	0133	0143
FILM (YES/NO)	N	N	N	N	N	N	N	N	N	N
COMMENTS						"THAT'S CHARLIE!" FROM PILOT	"IDENT B_{MOD} EASILY" FROM PILOT	PILOT COMMENT: "B_{MOD} SEEM BEST OVERALL"	IDENT "C" EASILY. "C" EASIER TO SEE BUT DIR. TO "PAD" NOT AS CERTAIN AS "B_{MOD}"	OBS. COMMENT: PILOT VARIES BETWEEN "C" AND "B_{MOD}" AS FAVORITE

FIGURE 11. SAMPLE OF DATA LOG SHEET

During the first portion of the flight evaluation period, while data collection techniques were still being evolved, a total of 30 approaches were accomplished without recording the observed departure ceiling heights. In addition, some few approaches for which data was obtained were conducted in IFR conditions, but during periods of weather improvement such that the data obtained was considered to be only marginally valid. All of these approaches were determined to be unsuitable for inclusion in the averaging procedure previously described as having been used to obtain the ranking of pattern with regard to effectiveness in providing first visual contact. Thus the following table, which shows the order of effectiveness for the three basic patterns, was developed with data from 74 out of the total 125 approach runs.

Pattern Displayed	Number of Approaches	Average Difference between Contact Ht. & Dep. Ceiling	Pattern Rank
A	23	111.10 feet	3rd
B*	28	127.90 feet	2nd
C	23	145.50 feet	1st

*includes approaches on both B and B_{mod} patterns

If the two different variations of the B pattern are considered separately, the B_{mod} pattern would be ranked below the C & B patterns for having a lower Average Difference between C.H. and D.C. of 119.90 feet. The average difference value for B pattern alone, without including the data for B_{mod} pattern approaches, then increases to a figure of 132.80 feet. Making this distinction between the B_{mod} pattern and the B pattern then, the table of ranks becomes:

Pattern Displayed	Number of Approaches	Average Difference Between Contact Ht. & Dep. Ceiling	Pattern Rank
A	23	111.10 feet	4th
B	19	132.80 feet	2nd
B_{mod}	9	119.90 feet	3rd
C	23	145.50 feet	1st

These results are not at all surprising, since increasing the number of lights within a pattern length and width which remains essentially constant will effectively increase the overall intensity of the approach lighting system and so increase the range at which it will first be detected. The amount of increase in overall effective intensity will depend on both the number of additional lights and their location or placement in relation to each other and to lights which are common to all

patterns (such as, in this case, the double row centerline portion of the system). In comparing the performance, from the standpoint of effectiveness in providing earliest visual contact, the additional lights within the C pattern have obviously resulted in a brighter, more easily detected system. Whether this same pattern also provides the superior "after-contact" guidance can only be determined by analysis of the subjective pilot comment and opinion data.

Subjective Data.

The pilot questionnaires, designed to reveal the relative effectiveness of each of the four approach lighting patterns in providing visual guidance after contact, were filled out immediately after the project actual weather flight evaluation was completed. The four subject pilots were afforded an opportunity to refresh their memories of pattern configurations and details of the flight sessions by viewing motion picture films taken during 28 of the actual weather approaches. They also listened to excerpts from tape recordings of their own spontaneous comments made in the helicopter during the flight sessions. Copies of each of the questionnaires as completed by the pilots, are included in Appendix A, along with a composite questionnaire showing a tabulation of the ratings given on each of the questions. The composite figures were arrived at by adding the rankings for each system on each question, assigning an intermediate rank of 1 1/2 points in the situation where two systems were adjudged equally good as to a specific feature. Thus, the lower the composite figure, the more effective the particular system was felt to be.

The "B_{mod}" pattern was overwhelmingly chosen as the most effective and desirable overall, ranking well above each of the other three patterns in all respects except that of producing the least offensive glare. With regard to that single quality, it was ranked second to the "A" pattern which contained the minimum number of lights.

The "B" pattern was ranked second in overall effectiveness and desirability, and superior to the third ranking "A" pattern in all respects other than the aforementioned glare producing tendency. It ranked lower than the "C" pattern in only one aspect, that of the amount of aircraft pitch attitude information provided, while being judged approximately equal to "C" in glare produced.

The "A" pattern was ranked in third place overall, and felt to be superior to the last ranked "C" pattern in all respects other than in the amount of aircraft pitch attitude information provided.

The "C" pattern was judged, unanimously, to be the least desirable, both in general and in detail, for providing visual guidance after contact.

Especially noted were spontaneous comments, recorded while airborne, to the effect that:

1. Pattern "A" might not provide immediate indication of offset direction to a pilot making contact with only one sideline of lights. It could leave some doubt in the pilot's mind as to the direction in which to turn in order to regain centerline position.

2. Pattern "C" might not provide immediate indication of the direction in which to fly upon first visual contact. The mass of lights formed a very bright, easily detected triangular shaped pattern, but did not provide a strong indication of the direction in which the remaining visual portion of the approach should be accomplished.

3. Pattern "B" provided the directional guidance required upon making visual contact, but could, under certain circumstances, create a glare condition and visual discomfort for the pilot.

It would have been possible to perform a statistical analysis of the questionnaire results, and such a course of action was considered. The procedure was rejected, however, in as much as the very limited number of responses (from four subject pilots) were insufficient for a valid statistical study. The very fact that all four subjects, completing their questionnaire evaluation independently, gave virtually identical responses in ranking the various patterns for effectiveness in a number of different respects gave support to the validity of the results. Such consistency of opinion and evaluation, even to specifics mentioned in the supplementary comments, indicated a strong probability that results obtained from such subjective data were reasonable.

In addition to the comments concerning the effectiveness of the pattern variations, the subject pilots occasionally offered suggestions for improving portions of the approach lighting system that were common to all of the configurations under test. As a case in point, several of the pilots indicated that they felt the effectiveness of the wing bars, located on either side of the landing pad and extending outwards for close-in roll and maneuvering guidance, could be improved by providing additional fixtures in the gap between the innermost lights and the pad edge. Since these lights were intended to provide guidance during the final phase of the landing maneuver, while close to the pad and well after "breaking-out," it was felt that the further minimal testing needed to resolve this question could be accomplished with scheduled VFR flights. Accordingly, the system installed at NATC Patuxent River was modified to add two additional lights per side, inboard of the test standard wing bar lights at 25 foot spacings, as indicated in Figure 9. A number of VFR approaches and landings with several different pilots were accomplished, displaying first the original wing bar configuration, then one additional

light on each side, and finally the two additional lights per side. Pilot opinion was unanimous in preferring the additional close-in guidance provided by the additional two lights on each side.

Analysis of Results.

The ranking of pattern effectiveness, as determined from the two different techniques of data collection, can be best summarized as follows:

Pattern Designation	Rank According to Objective Data	Rank According to Subjective Data
"A"	4th	3rd
"B"	2nd	2nd
"B_{mod}"	3rd	1st
"C"	1st	4th

At first glance, it would appear that the two forms of data collection evolved thoroughly conflicting results, and that the validity of any conclusions drawn from such data might well be invalid. It should be borne in mind, however, that each form of data collection was intended to evaluate a certain aspect of pattern performance or effectiveness. In particular, the objective data (observations of ceiling height, recording of breakout altitude, etc.) was decided upon as the most suitable technique for determing the best pattern for providing early visual contact and identification. The subjective data (pilot opinion, comments, preferences, etc.) was then chosen as the most valid indication of the degree of visual guidance that each pattern afforded after initial visual contact had been established.

We have, therefore a situation wherein the pattern chosen as most effective in providing early contact and identification, pattern "C," has also been judged least adequate from the standpoint of post-contact visual guidance capability. In other words, the pattern "C" configuration will attract the pilot's attention first, having the greatest "punch" or penetration, but thereafter offers the pilot only the minimum of attitude and directional guidance to lead him further on to a successful landing. Considering the situation a bit further, we find that this pattern "C" might possibly, under extremely low visibility conditions, induce a pilot to continue his approach, following a satisfying early "break-out," until he finds himself in a much closer-to-the-ground position than he would care to be, without sufficient guidance to enable him to complete his landing. Here then we have a possibly deceptive and dangerous situation developing, one that must count seriously against the "C" pattern as a choice for adoption as a standard.

On the other hand, and seemingly diametrically opposed to the pattern "C" case, we can see that the "B_{mod}" pattern which provided the maximum of visual guidance after contact with the system had been made, did not provide as satisfactory early identification or "pick-up" as did either the "C" or "B" patterns. This would seem to rule out the "B_{mod}" pattern also, leading us to accept the "B" pattern as the only reasonable choice, even though it was not determined to be outstanding in either category of qualifications. Examining the case for choosing the "B_{mod}" somewhat further, we can see that, unlike the "C" pattern, there appears to be no likelihood of a possibly dangerous situation developing for a pilot making an approach using the "B_{mod}" pattern. Since the system penetration or "punch" capability is somewhat less than that of either the "C" or "B" pattern, we must admit to the possibility that, in the worst case, the pilot will reach his "Decision Height" before making visual contact with the system, and therefore have to abandon his approach. This is perhaps a disappointing situation for the pilot, if it occurs, but altogether a safe operation nevertheless. On the positive side, however, we should remember that, with the "B_{mod}" system, the pilot can rest assured that he will have sufficient visual guidance from the system, once he makes contact, to safely continue his approach and landing maneuver.

Looking back once more to the table comparing the ranks it seems that pattern "B," having been chosen as 2nd most effective in affording early contact and providing after-contact guidance, might be a good choice overall. It can reasonably be expected to provide, approximately, a 13-foot advantage in contact height over the "B_{mod}" pattern. This is, accepting a figure of 600 to 700 feet per minute as an average helicopter "sink-rate," a time advantage of about two-thirds of one second. It does not seem reasonable to consider this as sufficient ground for judging the system to be superior to one preferred by all of the subject pilots for it's increased guidance capability and reduced potential for producing objectional glare. It should be remembered, when considering arguments for choosing between the "B" and "B_{mod}" patterns, that the latter was developed from pilot suggestions for improving the former.

The "A" pattern, having been determined to be least effective in providing early visual contact and next to last in guidance rank, did not merit further consideration. One pilot did comment, however, that it might provide suitable guidance, at somewhat lower cost, in better-than-IFR weather conditions and provide a suitable base for economical expansion to a "B_{mod}" pattern when required at a later date.

Pilots indicated that they considered the 100 percent intensity setting, used on all systems except those of the pad wing bars, quite suitable for the visibility conditions flown, and stressed the need for balanced lighting intensities throughout the system.

CONCLUSIONS

Based on the results of this evaluation effort, it is concluded that:

1. The helicopter approach lighting pattern referred to as "B_{mod}" in this report is the most effective of those tested in providing visual approach guidance at decision heights of 200 feet or less and for approach glide path angles of 6° or less under IFR weather conditons.

2. The other three approach lighting patterns evaluated, referred to as "A," "B," and "C" in the report, while providing a usable measure of visual guidance for the conditions stated, proved substantially less effective than the "B_{mod}" pattern referenced above.

APPENDIX

PILOT QUESTIONNAIRES

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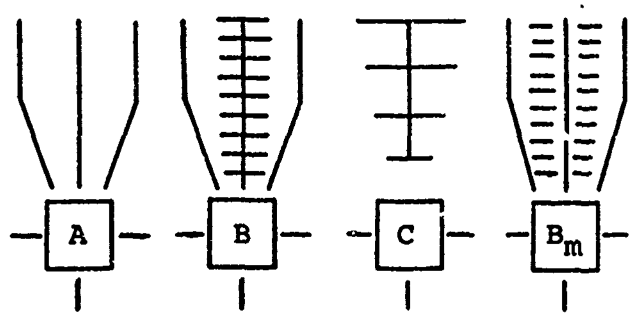
HELIPORT IFR LIGHTING EVALUATION
PILOT'S RATING SHEET

PILOT: "L" AIRCRAFT TYPE: UH-1H Helicopter

DATE: Oct'71 to May'72 TIME OF DAY: Day & Night LOCATION: NAFEC

WEATHER: 200' to 500', ¼ to 1½ mile, rain/fog
(Ceiling, Visibility, Type of Vis. Restriction, ETC.)

Note: Please rate all patterns on all features by entering a number in each blank, using 1 to mean most effective, 2 to mean second best, etc.



	A	B	C	B_m
1. Provides unique and unmistakable identification of the approach to the helipad.	2	1½	3	1½
2. Provides approach course alignment information.	1½	2	3	1½
3. Provide information about rate of closure with helipad.	2	1½	3	1½
4. Provides aircraft pitch attitude information.	2	1½	3	1½
5. Does not produce objectionable glare conditions.	1½	3	2	1½
6. Overall system effectiveness and desirability.	2	1½	3	1½

7. Other comments, suggestions, etc.

"B" is best except for 2 items in which "A" is best. "B" would move to best in all categories if the so-called "B_{mod}" replaced it.

Note: All light intensities should be equal.

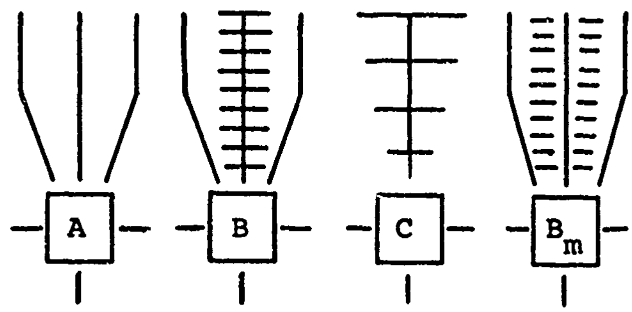
HELIPORT IFR LIGHTING EVALUATION
PILOT'S RATING SHEET

PILOT: "P" AIRCRAFT TYPE: UH-1H Helicopter

DATE: Oct'71 to May'72 TIME OF DAY: Day & Night LOCATION: NAFEC

WEATHER: 200' to 500', ¼ to 1½ mile, rain/fog
(Ceiling, Visibility, Type of Vis. Restriction, ETC.)

Note: Please rate all patterns on all features by entering a number in each blank, using 1 to mean most effective, 2 to mean second best, etc.



	A	B	C	B_m
1. Provides unique and unmistakable identification of the approach to the helipad.	4	1	3	2
2. Provides approach course alignment information.	3	2	4	1
3. Provide information about rate of closure with helipad.	4	2	3	1
4. Provides aircraft pitch attitude information.	4	3	1	2
5. Does not produce objectionable glare conditions.	1	3	4	2
6. Overall system effectiveness and desirability.	3	2	4	1

7. Other comments, suggestions, etc.

The "B_{mod}" appears most favorable while flying the UH-1H. Must verify these results with other (large) helicopters. I feel with the "B_{mod}" pattern that minimums of 1/8th mile (vis.) would not be unreasonable. Intensities did not seem to present a problem.

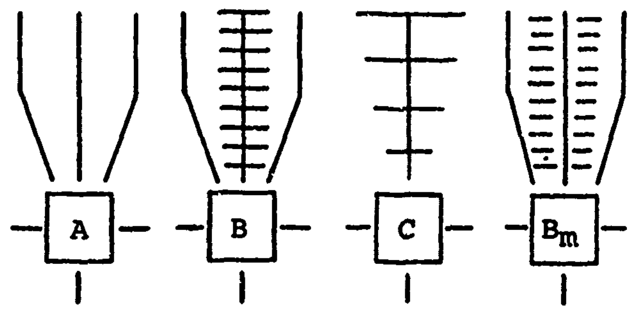
HELIPORT IFR LIGHTING EVALUATION
PILOT'S RATING SHEET

PILOT: "D" AIRCRAFT TYPE: UH-1H Helicopter

DATE: Oct'71 to May'72 TIME OF DAY: Day & Night LOCATION: NAFEC

WEATHER: 200' to 500', ¼ to 1½ mile, rain/fog
(Ceiling, Visibility, Type of Vis. Restriction, ETC.)

Note: Please rate all patterns on all features by entering a number in each blank, using 1 to mean most effective, 2 to mean second best, etc.



	A	B	C	B_m
1. Provides unique and unmistakable identification of the approach to the helipad.	4	1½	3	1½
2. Provides approach course alignment information.	3	2	4	1
3. Provide information about rate of closure with helipad.	4	1½	3	1½
4. Provides aircraft pitch attitude information.	4	3	1	2
5. Does not produce objectionable glare conditions.	1	4	3	2
6. Overall system effectiveness and desirability.	3	2	4	1

7. Other comments, suggestions, etc.

"B_{mod}" is considered best. "A" is inadequate for daylight. There is considered to be very little difference between "B" and "C"; both provide too much glare at night. "C" appeared to be better after a learning period, but still not as good as "B_{mod}" or "B".

HELIPORT IFR LIGHTING EVALUATION

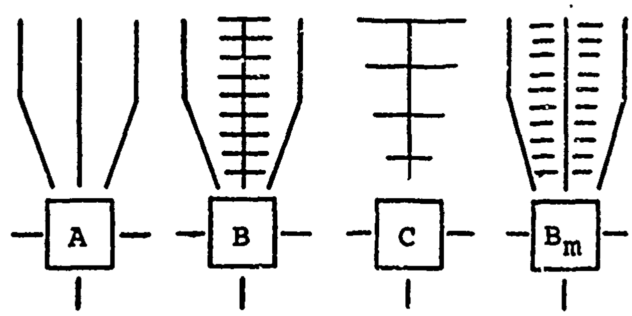
PILOT'S RATING SHEET

PILOT: "B" AIRCRAFT TYPE: UH-1H Helicopter

DATE: Oct'71 to May'72 TIME OF DAY: Day & Night LOCATION: NAFEC

WEATHER: 200' to 500', ¼ to 1½ mile, rain/fog
(Ceiling, Visibility, Type of Vis. Restriction, ETC.)

Note: Please rate all patterns on all features by entering a number in each blank, using 1 to mean most effective, 2 to mean second best, etc.



	A	B	C	B_m
1. Provides unique and unmistakable identification of the approach to the helipad.	2	3	4	1
2. Provides approach course alignment information.	2	3	4	1
3. Provide information about rate of closure with helipad.	3	2	4	1
4. Provides aircraft pitch attitude information.	3	2	4	1
5. Does not produce objectionable glare conditions.	1	3	4	2
6. Overall system effectiveness and desirability.	3	2	4	1

7. Other comments, suggestions, etc.

(A) Initial ident. with low ceilings more evident with the higher light concentration at the approach end, i.e. light load such as "C" & "B"
(B) With cross wind from left, lights were blocked to co-pilot. Most adverse situation for pilot was strong cross-wind from the right.
(C) Move wing-bar lights closer to the pad, peripheral loss in close over the pad.

HELIPORT IFR LIGHTING EVALUATION

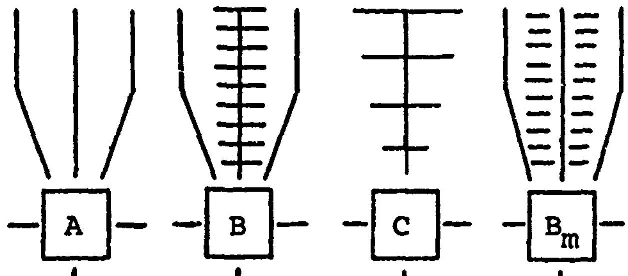
PILOT'S RATING SHEET

PILOT: Composite of 4 pilots AIRCRAFT TYPE: UH-1H Helicopter

DATE: Oct'71 to May'72 TIME OF DAY: Day & Night LOCATION: NAFEC

WEATHER: 200' to 500', ¼ to 1½ mile, rain/fog
(Ceiling, Visibility, Type of Vis. Restriction, ETC.)

Note: Please rate all patterns on all features by entering a number in each blank, using 1 to mean most effective, 2 to mean second best, etc.



	A	B	C	B_m
1. Provides unique and unmistakable identification of the approach to the helipad.	12	7	13	6
2. Provides approach course alignment information.	9½	9	15	4½
3. Provide information about rate of closure with helipad.	13	7	13	5
4. Provides aircraft pitch attitude information.	13	9½	9	6½
5. Does not produce objectionable glare conditions.	4½	13	13	7½
6. Overall system effectiveness and desirability.	11	7½	15	4½
Totals	63	53	78	34
Rank	(3)	(2)	(4)	(1)

7. Other comments, suggestions, etc.